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DIGITAL INTERFACE FOR NDT INSTRUMENTS

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In order to obtain access to a computer from ordinary NDT instruments, a special interface was made which acts as the buffer between the computer, and the real world. This presentation describes the special purpose interface, which was designed and built by Group M-1 of the Los Alamos Scientific Laboratory. This interface was primarily built for use with various ultrasonic equipment, but is actually a general purpose system that can perform data acquisition and control for other tests.

The entire interface consists of several subsystems which can be considered interfaces in themselves, but they are all contained or controlled from a common chassis block. These subsystems are described in Table 1. The interface is tied to a DEC PDP-9 minicomputer which is a 18-bit machine. The logic levels are also -3V and ground. Level shifting to conventional TTL levels was accomplished using standard DEC series logic. Each subsystem in the interface has

Table 1

Interface Subsystem Listing

- Display unit (Tektronics 601 Display Scope)
- Plotter unit (Hewlett Packard 7004 X-Y Recorder)
- Programmable Clock
- Analog to Digital Converter (ADC)
- 24 Channel Analog Multiplexer (MUX)
- 4-Axis Stepping Motor Drive
- 16 User Interrupts
- Analog Signal Conditioning Circuitry
- Output Pulse/Level Module
- Biomation 8100 Port
- 8 trigger pulse outputs

a set of commands which are moved to the device from the accumulator via IOTs. In certain cases, data are added to the lower bits of the command for transfer to the device. The IOTs and commands are shown in Table 2 along with their functions. The operation of each unit is described below. Each unit is operated by a device handler type subroutine which is FORTRAN callable.

Display Control

The display can be operated in either a store or nonstore mode. The nonstore mode either requires a continuous software refresh or a camera to record single or multiple display cycles. The store/nonstore mode is latched by the setting of a command and is usually set in the store mode as part of the initial subroutine call. The erase command does not change the mode, and any new display information is stopped until the erase cycle is completed. Each point plotted takes a total of three software commands. These are load X DAC, load Y DAC, and intensify point. The 10-bit X- and Y-data values are added to the appropriate commands. After a short delay of about 10 μ seconds, the display interrupt flag is raised. This amounts to a maximum value of 1777g. This flag verifies the completion of the point display cycle. The display and the point plotter generate the same information with the display typically being used to verify preliminary information prior to the more time consuming plotting routine.

Point Plotter

The point plotter control is essentially the same as the display control except that the mode commands are not necessary.

Clock

The clock, MUX, and the ADC are all interrelated in that a single IOT sets up the control for all three. The command word is again passed into the device from the accumulator. The clock has its own interrupt, start command, and interval register. The basic clock operates at 1MHz and is also run through seven decade counters to give a total of eight program selectable frequencies. The selected frequency is fed into a 12-bit binary counter where count is compared with the programmed count. When the two counts are equal, a done pulse is issued. This pulse resets the counter to zero. The command word is the sum of the command 10000g, the frequency F0000g, and the count C000g. This looks like 2F0000g. Four other commands determine the routing of the done pulse. These four commands actually set the state of two R-S flip-flops. 400000 and 500000 set the routing so that clock pulse will either start the ADC cycle or set the clock interrupt. 600000 and 700000 set the routing so that the clock is either disabled at the end of the cycle or automatically restarted.

ADC

The ADC is basically a DEC-module which accomodates inputs of 0 to +10V and has a 10-bit output. It is coupled with a sample-and-hold circuit. The sample-and-hold circuit is held in the follow mode by the ADC controller. Upon a sample command, the mode is changed to hold and 0.5 μ seconds later a convert pulse is issued. When the conversion is complete, a done pulse is issued which returns the sample-and-hold circuit to the follow mode and raises the ADC interrupt flag. As mentioned above, the sample command can come either from the clock or from a program generated IOT depending on how the clock control is set.

Table 2

Interface Command Structure

<u>MNEMONIC IOTs OCTAL</u>		<u>DESCRIPTION</u>	
DSSF	701401	SKIP ON DISPLAY FLAG	
DSCL	701402	CLEAR DISPLAY FLAG	
DSL D	701404	AC→ DISPLAY CONTROL AND DACS	
PLSF	701501	SKIP ON PLOTTER FLAG	
PLCL	701502	CLEAR PLOTTER FLAG	
PLI D	701504	AC→ PLOTTER CONTROL AND DACS	
CLR	701601	CLEAR LEVEL REGISTER	
SCMD	701604	AC→PULSES AND TOGGLE REGISTER	
CCMD	701605	CLEAR REGISTER, AC→ PULSES/REGISTER	
ADSF	703401	SKIP ON ADC FLAG	
ADCL	703402	CLEAR ADC FLAG	
ADRD	703452	CLEAR ACCUMULATOR, READ ADC BUFFER	
ADLD	703404	AC→MUX/ADC CONTROL	
KLSF	703501	SKIP ON CLOCK FLAG	
KLCL	703502	CLEAR CLOCK FLAG	
PLSE	703504	OUTPUT PULSES	
BMSF	703601	SKIP ON BIOMATION FLAG	
BMRC	703612	CLEAR ACCUMULATOR, READ BUFFER	
BMCL	703604	CLEAR BUFFER AND FLAG	
USSF	703701	SKIP IN USER INTERRUPT FLAG	
USR D	703712	CLEAR ACCUMULATOR, READ BUFFER	
USCL	703704	CLEAR BUFFER AND FLAG	
DISPLAY COMMANDS (701404)		PLOTTER COMMANDS (701504)	
200000	LOAD X DAC	200000	LOAD X DAC
400000	LOAD Y DAC	400000	LOAD Y DAC
600000	DISPLAY	600000	PLOT
040000	SET NONSTORE MODE		
100000	SET STORE MODE		
140000	ERASE		
ADC/MUX/CLOCK COMMANDS (703404)			
000000	SAMPLE	400000	CLOCK DONE ADC, SAMPLE DISABLED
100000	LOAD MUX REGISTER	500000	CLOCK DONE PI, SAMPLE ADC
200000	LOAD CLOCK REGISTER	600000	CLOCK DONE RESETS AND RESTARTS CLOCK
300000	START CLOCK	700000	CLOCK DONE RESETS CLOCK, NO RESTART

MUX

The MUX is simply a series of 24 analog gates which can be selected one at a time. Once selected that channel stays active until the selection is changed. The channel is selected by one of the commands in the ADC/MUX/CLOCK set. The structure is 1000NN₈. The command can select up to 64 channels but only 24 are currently implemented.

User Interrupts

This device allows the inspection system to output up to 15 interrupts organized on a priority basis which looks like one program interrupt. The highest interrupt code is then read from a buffer and interpreted by software.

Analog Signal Conditioning

This section contains 4 op-amp buffers which perform amplification and level shifting of incoming signals. The outputs are normally connected to four channels of the MUX. The purpose of these buffers is to allow adjustment of incoming signals to fit the characteristics of the ADC. The circuits can provide up to 10X amplification with a level shift of about ± 8 volts. Two 50-ohm buffers with unity gain are also included for connecting high impedance outputs to the Biomation 8100 transient recorder, which has a 50-ohm input impedance.

Output Pulser and Levels

This module outputs one 18-bit word both as 1- μ second pulses and as levels. This module is used to output commands to the Biomation transient recorder and to the stepping motor driver. The level outputs are or-ed with the existing outputs so that normally the level buffer is cleared before loading.

Trigger

Eight independent trigger pulse lines are available for control as needed. The pulse address is loaded into the accumulator as N₈ and the PLSE IOT is issued.

Biomation Interface Buffer

This device merely serves to recognize when data is available from the recorder and to read the data into the accumulator on command.

4-Axis Stepping Motor

This is actually an external chassis which is capable of driving one of four stepping motors upon command. This command normally comes from the interface in the form of pulses, but front panel control is also available for set-up and manual operations. The command is structured as 7XANN₈: 7₈ is the Controller address, A₈ is the Axis and direction, and NNN₈ is the number of steps desired to a maximum of 255. The least significant bit of A₈ denotes the direction and the other two bits indicate the motor number. The driver signals

the user interrupt device when the desired action is complete and also if a limit switch was reached. The driver is currently connected to a small X, Y, Z scanner.

APPLICATIONS

The interface has been primarily used in the ultrasonic inspection of equatorial welds in spherical vessels. For this application, a FORTRAN program with a Macro subroutine was written to control the inspection. The subroutine contains all of the routines required to operate the display, ADC, clock, MUX, and interrupt interpreter. The main program controls the inspection process via teletype commands.

The operator enters the test description and a series of instrument parameters as the first step and then will normally input known amplitude input signals for test calibration and plotter grid lines. Up to 11 different signal levels are converted and stored in an array. Normally these represent signals from 0 to 100% full scale amplitude at 10% increments.

When the inspection is formally started by the command SCAN, the test description, parameters, and amplitudes are stored as an unformatted logical record on DECtape. A dummy record of 1024 words is also written following the header block.

The scanning fixture has a zero degree indicator which is tied to the user interrupt register. When this interrupt occurs, data collection is initiated. This continues under a clock control until a total of 1024 samples have been taken. The clock timing is set so that 1000 sampled points represent one revolution of the object. The software also recognizes when the second interrupt occurs at about sample 1000 in the scan and negates the datum. At the completion of the scan, the operator is asked if the scan was acceptable. If it was, the program compares the data to an array containing previously determined maximum values of each location in the array and replaces the stored value with the new value if the latter is greater. The value of the last word in the array is replaced with the current scan count and the array is written into DECtape. The transducer is moved to the next position and another scan is taken. If the previous scan was not accepted by the operator, the scan is ignored and no comparison or storage occurs. The operator can close out the inspection by indicating DONE when queried about any scan. Upon this command, the comparison and scan number are written onto DECtape with the scan number being negated before writing to indicate the end of the sequence. The next block of the DECtape also has a record written onto it that indicates the last valid record on the tape. The tape unit is then backspaced until the dummy block following the header information is reached. The contents of the maximum value array are written into this record and then the DECtape repositions itself to write over the last valid record. The program then asks if further inspections are desired. A printout of a typical inspection sequence is shown in Figure 1.

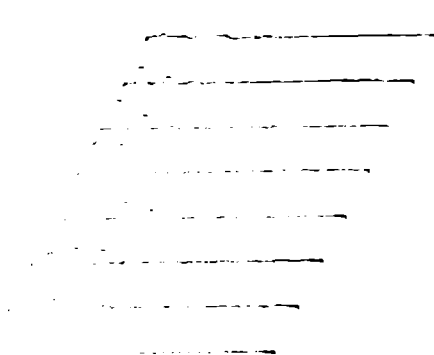
The second step in the inspection cycle is to retrieve the data from the DECtape. This requires a second program due to memory limitations on the computer. The operator enters the ID line for the inspection desired. When this

ID is found, the contents of the header block are printed out. Three formats are used for plotting the data. The first and easiest at this point is a maximum amplitude plot. This format plots the value of the maximum amplitudes over a plot of the grid lines. This plot is useful in that it gives the value of the maximum amplitude, but does not require extremely accurate orientation of the item to achieve this end. The second format is an isometric plot of the data by scan in order. Amplitude compression and projection angle can be varied. This gives a picture of how the amplitudes varied from scan to scan. The third is a polar plot similar to the one generated using a X-Y recorder and sin-cos potentiometer. The threshold for the amplitude of points plotted may be set at any of the grid line levels.

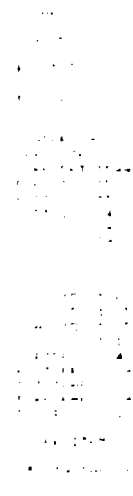
These three plots are shown in Figures 2 and 3 for EDM notches 5, 10, 20, and 30% of the wall thickness in a welded spherical vessel. The notches evaluated in Figure 2 are located in parent material and the notches represented by Figure 3 was placed in the weld root zone.

A second application was the use of the system to evaluate plated spherical assemblies. The assembly consisted of a nickel layer plated on an inner shell. Ultrasonic thickness measurements are used to guide the machining of the outer contour so that nickel plating will be concentric about the center. The same scanning fixture is used. The analog thickness signal from the Erdman Model 1176 HIRE ultrasonic instrument is fed into the ADC after conditioning. The data is plotted out over a grid of a relative thickness. Other applications include transducer characterization of beam pattern using the X-Y-Z scanner and eddy current probe scanning in a X-Y raster. At this point, the most difficult part is complete and adapting the setup to meet new applications is relatively simple.

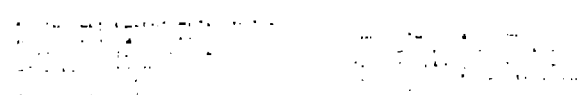
a) Maximum Amplitude Plot



b) Polar Plot

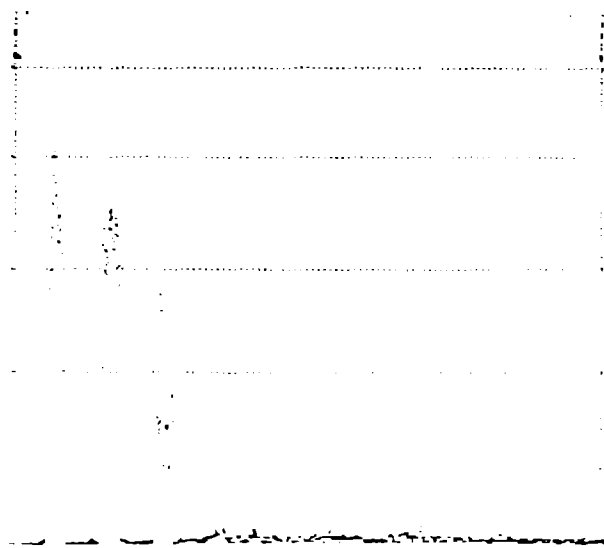


c) Isometric Plot

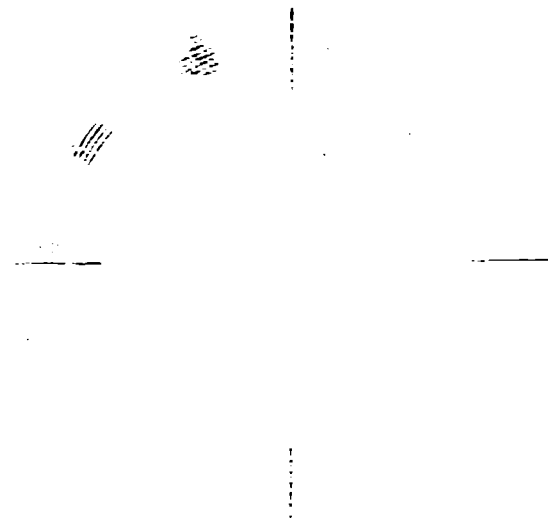


d) Test Identification

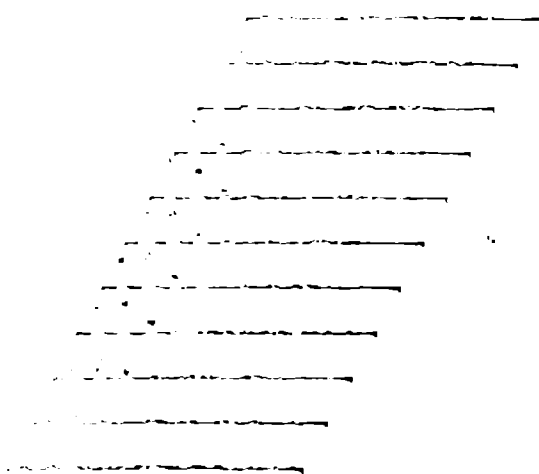
Figure 2. Inspection Results with Notch in Parent Material



a) Maximum Amplitude Plot



b) Polar Plot



c) Isometric Plot

TEST RESULTS
 TEST NO. 1
 TEST NO. 2
 TEST NO. 3
 TEST NO. 4
 TEST NO. 5
 TEST NO. 6
 TEST NO. 7
 TEST NO. 8
 TEST NO. 9
 TEST NO. 10
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 TEST NO. 99
 TEST NO. 100

TEST RESULTS
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TEST RESULTS
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d) Test Identification

Figure 3. Inspection Results with Notches in Weld